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Service-Oriented Enterprises and Architectures: State of the Art and Research Opportunities

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Abstract

To survive in the global marketplace, organizations need to continually adapt to the changing business environment. Information systems play an ever increasing role in helping organizations achieve this objective. Recently, there has been considerable attention paid to the service orientation and how it could alter the way organizations function and their relationships with business partners such as suppliers. In this research, we focus on service-oriented enterprises and architectures. In doing so, we bring to the fore the current state of the art in the emerging service paradigm. Service-oriented computing is revolutionizing the way corporations manage information so as to enable streamlining the various stages of computing including strategic planning, business process management, operations processing, and information technology services. We demonstrate how the application of service orientation to a supply chain will lead to service-centric supply chains that offer significantly more enterprise agility. We also discuss opportunities for future research in the new paradigm.

Keywords: *service-oriented architecture, enterprise systems and applications, services computing, web services*

Introduction

Today, organizations are facing greater challenges than ever before due to the fast advances in technology, rapidly changing customer demand, fierce competition from globalization, and increasing levels of system complexity. In order to survive and excel in such a dynamic business environment, organizations must be able to adapt and respond to changes efficiently and effectively, which is often referred to as enterprise agility (Zhao et al. 2007). Enabled by web services technology, Service Oriented Architecture (SOA) has become the mainstream IT architecture that many organizations leverage to transform their enterprise infrastructures to achieve higher level of agility (Erl 2004). In SOA, the business processes of an organization are composed by a set of linked autonomous services, often implemented as web services. These services represent repeatable business tasks and can be accessed on demand via standard interfaces over a network, enabling the business to quickly adapt to changing conditions and requirements (Peltz 2003). SOA also helps organizations realize the maximal reuse of their existing IT assets by building services from existing components and accessing legacy systems via standard web service interfaces. Gartner Research predicted that SOAs will enable organizations to increase code reuse by more than 100% by 2008 and 80% of application software revenue growth will come from products based on SOA (Hayward 2005). In addition, early SOA market is maturing as indicated by the accelerated SOA implementation and adoption in the past several years. According to a recent survey by AMR Research, the number of respondents planning to evaluate or implement SOA in the next 24 months has jumped from 53% in 2005 to 81% in 2006 (Gaughan and Finley 2006).

SOA is "an application architecture within which all functions are defined as independent services with well-defined invokable interfaces which can be called in defined sequences to form business processes" (Channabasavaiah et al. 2003). Those independent services may include purely business functions, business transactions composed of lower-level functions, or system service functions and can be accessed without any knowledge of their underlying implementation details. IBM defines that a SOA contains four core components, namely, business services, integration services, enterprise service bus, and infrastructure services, which work together to support on-demand business (Keen 2004). IBM also develops a SOA reference architecture that defines the comprehensive IT services required to support the entire SOA implementation life cycle (IBM 2005). SOA also promotes process-centric architecture as opposed to the existing program-centric architecture by leveraging workflow technology as an integration hub to coordinate independent business services to add value (Leymann et al. 2002; Zhao and Cheng 2005). The service paradigm has been embraced by the software industry, indicated by the wide array of SOA platform offerings, such as SAP NetWeaver, Oracle Fusion, and IBM Websphere.

As a SOA enabling technology, web services provide the latest approach to address application integration problem, a key challenge that tops the priority list of many CIOs (Channabasavaiah et al. 2003). W3C (2002) defines web service as a "software application, identified by a Uniform Resource Identifier (URI), whose interfaces and bindings are capable of being defined, described and discovered by eXtensible Markup Language (XML) artifacts, and supports direct interactions with other software applications using XML-based messages via internet-based protocols." Web services is a collection of technologies, including XML, Simple Object Access Protocol (SOAP), Web Services Description Language (WSDL) and Universal Description, Discovery and Integration (UDDI) (Ferris and Farrell 2003). The self-describing nature of XML and WSDL allows disparate software components to communicate with each other. Built on top of XML, SOAP provides the standardized mechanism for exchanging document-centric messages and invoking remote procedure calls between software components via Internet. UDDI represents a set of protocols for the description, registration, discovery and integration of software components. Web services technologies provide a language-neutral, platform-neutral, and environment-neutral programming model to provide application integration solutions (Gottschalk et al. 2002). As a result, web services have gained industry-wide acceptance as the universal standard for enterprise application integration (Kreger 2003).

Web-services-enabled SOA has not only created tremendous business opportunities for IT industry but also stimulated research endeavors from various academic disciplines, such as computer science, engineering, management information systems, to name a few. Many major MIS journals have dedicated special issues to web services and SOA related topics, e.g. IEEE Computer special issue on web services computing (Chung et al. 2003), Communication of the ACM special issues on service-oriented computing (Papazoglou and Georgakopoulos 2003) and services science (Chesbrough and Spohrer 2006), Decision Support Systems special issue on web services and process management (Zhao and Cheng 2005), and most recently Information System Frontier special issue on services computing for enterprise agility (Zhao et al. 2007). In this paper, we discuss the state-of-the-art of this exciting area on service-oriented enterprises and architectures based on our experiences from various SOA related projects in both academia and industry, and propose a number of possible research directions.

Emerging Architecture of Business

A recent global survey of 765 CEOs (Global CEO Study) reveals the intention of businesses to invest significantly in transformation and growth in the coming years and that successful businesses will realize their aggressive business transformation objectives through continuous innovation and improvement rather than organically. CEOs are looking to innovate not only what they produce but also the structure and operations of their businesses. Such a fundamental re-conceptualization of what the business is about (business strategy) and how they operate (business operations) requires a new architecture of business, referred to as the services-oriented enterprise.

Service-oriented computing holds significant promise in shaping the architecture of future businesses, through flexible alignment of business and IT. There are many different approaches that enterprises are using to apply SOA principles. Figure 1 shows a model-driven architectural framework developed by IBM Research for transforming businesses to be service-oriented (Kumaran and Bhaskaran 2005). Such a framework can be applied progressively to transform enterprise processes and information systems. Service-oriented enterprises have significant competitive advantage over their industry peers as they have the ability to continuously innovate and improve their business processes to adapt to the changing needs of their customers and markets.

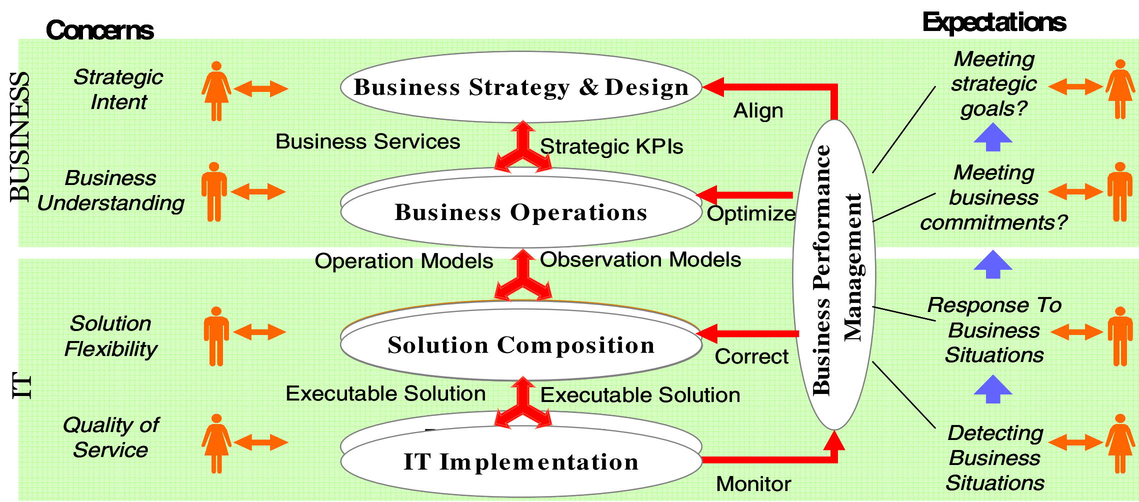

Figure 1: Service-oriented Enterprise Transformation Framework

Service-orientation is not only about building IT systems using SOA but also encompasses the transformation of an enterprise through the alignment of business and IT to be efficient and effective. The predominant focus in literature and in practice with regards to SOA is about IT with accompanying challenges of identifying, specifying and realizing services in a distributed and heterogeneous IT environment. There is increasing awareness that such an approach although useful in the early days of SOA is really unsustainable at the enterprise level. Why should the line-of-business care about service-orientation? Service-oriented enterprise as an emerging architecture-of-business takes the view that service-orientation helps to execute the business strategy of an enterprise with significant multi-dimensional benefits (flexibility to change, enhanced quality, effectiveness), in less time (time-to-value) and cost (efficiency) using IT.

- **Business Design: Strategic Intent**

CEOs are beginning to initiate systemic changes to create new business designs that take advantage of service-orientation to constitute globally-integrated enterprises. Enterprises are treating business functions and operations as component pieces (i.e. business services) that they can re-assemble in new combinations based on strategic judgments about what aspects of the business they want to excel and what aspects they would rather have partners execute (Palmisan, S.,). Such business strategy and design concerns are addressed at the very top layer of the service-oriented enterprise transformation framework (shown in Figure 1) yielding the identification of business services and strategic performance indicators for the enterprise.

- **Business Operations: Process Architecture**

Business processes help to formally and explicitly capture the understanding of how a business operates, i.e., what work is essential to be performed, when, in what order, by whom, and how to generate business value. Processes characterize the structure and behavior of business services that constitute a business design. The enterprise business processes and the relationships between them are referred to as the process architecture of an enterprise. Business process management (BPM) is emerging as the new technology-enabled management discipline with focus on explicit end-to-end business processes and organization roles aligned by business processes rather than by business functions. Some market analysts even hold the view that enterprises that are aggressively transforming their enterprises to be process oriented will be highly successful in leading their respective industries (Gartner,).

SOA typically involves the choreography of services that are stateless. Such services are provided either by information systems within an enterprise or by business partners outside of an enterprise. So where is the data? Traditionally data has been spread across myriad application silos and enterprise information systems resulting in poor visibility and inhibiting business agility. With the focus on BPM, increasingly data that the business cares about is migrating from the myriad application silos to the processes. Processes reinforce the centrality of information in enterprises and provide the information context for the service choreography in SOA.

Business Process Modeling, Analysis and Simulation are therefore important capabilities for studying the business operations, discovering opportunities for improvement, and introducing operational innovation. Business processes must also make explicit the business policies and rules that define the business operations. For example, an order management process may have policies on customer priorities such as a gold customer is processed with higher priority.

- **Solution Composition: Assembly of Services**

Business processes serve as the basis for identifying the services that are required and the granularity of these services (SOMA). The solution or service composition is typically done by IT architects taking into consideration the services that are identified from business processes as well as those that are discovered from existing information systems or provided by business partners. Additionally, non-functional requirements such as security and performance considerations influence the solution composition. The outcome of the solution composition is a service assembly that makes up the solution design expressed typically in platform-independent manner using a language such as the Unified Modeling Language (UML). There are many proprietary and open-source tools available that support UML (UMLTools).

IBM Research has introduced the Model-Driven Business Transformation (MDBT) approach that uses generative design patterns and a specialized UML vocabulary (also referred to as UML Profiles) to generate UML solution designs from business processes (Bhattacharya et al. 2005). Such designs are then iteratively refined consistent with the business processes to yield business-driven IT solutions.

An emerging trend is the development of pre-packaged process applications that are essentially mash-ups of application services (Gartner,). These so-called composite business services or service-oriented business applications are used as building blocks in assembling solutions rapidly to customer requirements (Gartner,). Another noteworthy trend is the dynamic assembly of services that are available on the Internet using Web 2.0 technologies. Today most of these so-called mash-ups are largely for social applications such as crime maps that are mash-ups of crime statistics provided by local police departments, Yahoo Geo-coding and Google Maps. A number of enterprises are also beginning to use similar mash-up technologies and approaches to build what are referred to as situational applications. However, mash-ups have still some ways to go before they are well accepted for industrial strength service-oriented enterprise applications.

- **IT Implementation: SOA Foundation**

The service assembly that makes up the solution design is converted into an executable solution that is expressed using J2EE and Web Services programming model. There are many middleware vendors who provide IT platforms for SOA solutions that are based on relevant Web Services, Java and XML standards. IBM provides a comprehensive SOA Foundation based on the Service Component Architecture (SCA) programming model that allows services to be realized using service components whose interface can be expressed using either Java or Web Services (Ferguson and Stockton 2005). A service component by definition must specify: the interfaces that the component provides, the implementation artifact (e.g. bpel, java), policy assertions on what the container should provide (e.g. ws-reliablemessaging), optionally the interfaces that are required from other components, optionally the resource that is managed (such as support for ws-resourceframework), and optionally any relevant operation sequence. Open source versions of the SCA are also available (see Tuscany -- http://cwiki.apache.org/TUSCANY/).

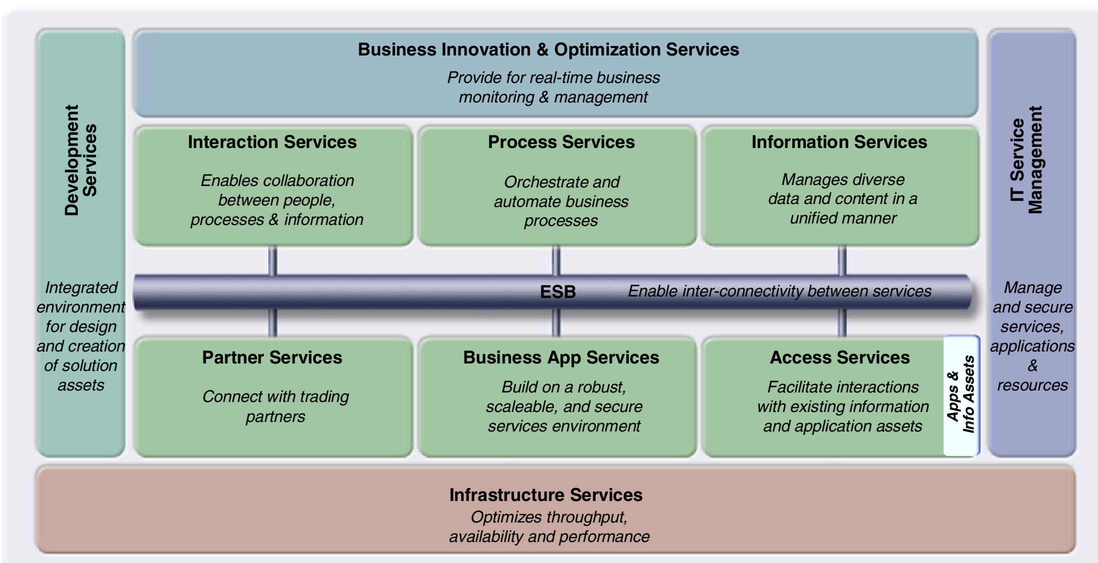

Figure 2: SOA Foundation

The SOA foundation typically consists of IT services that allow the coordination of people, processes and information systems (see Figure 2). An important capability and design pattern in the SOA foundation is the Enterprise Services Bus (ESB). The ESB is a multi-protocol fabric for the interoperability of services and it supports various architectural styles of integration including event-driven, message-oriented and service-oriented. The ESB accommodates both structural and behavioral compositions at the programming model level using mediations and service choreographies respectively.

- **Business Performance Management: Sense & Response**

The Service-oriented Enterprise is not a static assembly of services but one that can be dynamically adapted to accommodate change and provide business flexibility and agility. The capability to monitor, manage and dynamically adapt the service-oriented solution is referred to as the Business Performance Management (see Figure 1). Performance management concerns cut across all levels of the service-oriented enterprise transformation. Balanced scorecard (Kaplan and Norton 1992) is a strategy management tool that is often used in enterprises to provide a comprehensive view of business performance at the business design level in terms of business goals and strategic performance measures.

The strategic performance concerns and intent are then translated to specific business events that are raised within a solution design. Such events are observed, correlated and used to compute the Key Performance Indicators (KPIs). The network of KPIs constitutes an observation model that is used to monitor various aspects of the solution and raise alerts either reactively or proactively. Alerts can be responded either automatically by the system (e.g. launching a process to respond to an alert situation) or by human users through dashboards. IBM Research has developed a real-time sense & response services framework for business performance management (Chowdhary et al. 2006) as shown in Figure 3.

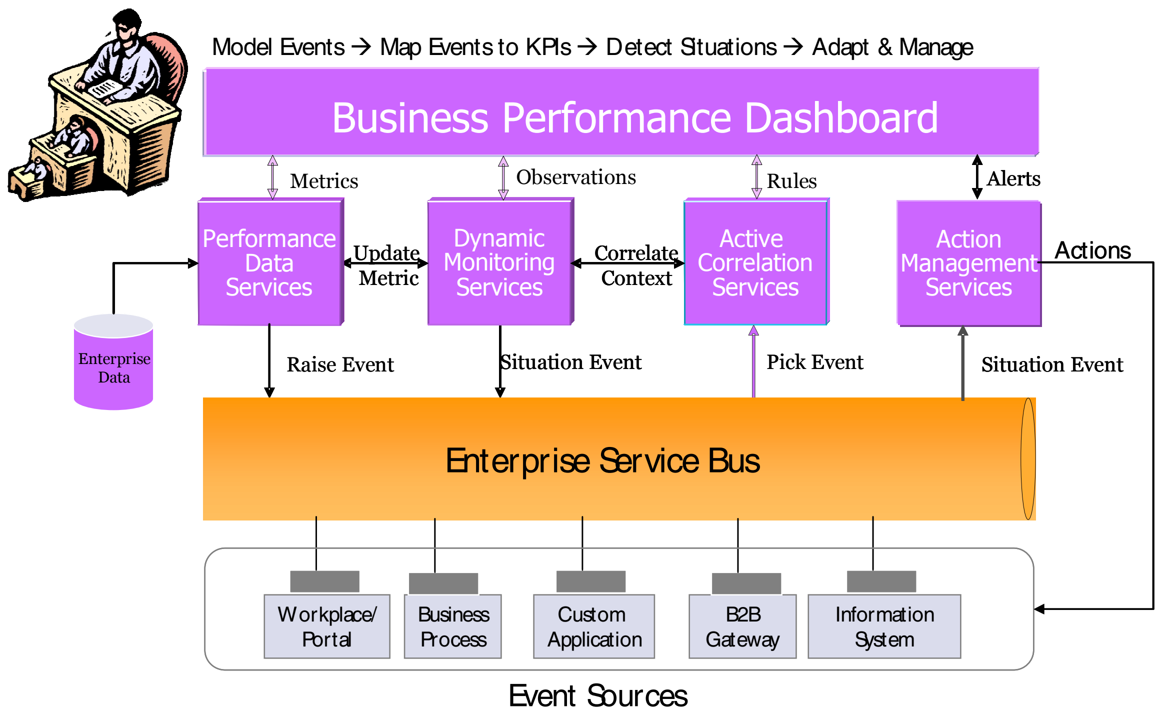

Figure 3: Sense & Response Services Framework

Events originate from various sources in a service-oriented solution. An emerging standard for expressing such events is the Web Services Distributed Management Event Format (WEF), an OASIS standard (see www.oasis-open.org). The sense & response services framework uses choreography of services to garner events, compute KPIs, detect situations of interest based on business rules, and then launch actions to adapt and manage the solution through real-time performance dashboards.

Service-Oriented Supply Chains

The emerging "architecture of business" in the last section offers unprecedented system flexibility, thus enabling more enterprise agility (Zhao et al. 2007). Next, we illustrate a scenario that takes advantage of service-oriented computing to support service-oriented enterprises, leading to service-oriented supply chains. This service-oriented enterprise application illustrates the tremendous economic impacts of service-oriented architectures.

To improve business performance via e-business, the manufacturing and service industries have been taking major initiatives to innovate their supply chains, and more and more business processes are automated via the Internet, leading to end-to-end integration of supply-chain processes (Matchette and Lee, 2004). As a good example of supply-chain process innovation, Ford has outsourced its logistics to UPS, resulting in a reduction of its car delivery time by 40%, and furthermore, UPS helped Ford to develop a tracking system and made it easy for 6,500 Ford car dealers to track down the models most in demand (Business Week, July 19, 2004).

According to Hau Lee (2004), companies have focused on achieving agility of their supply chains to respond to uncertainties, adaptability to changing supply conditions, and alignment among the entire supply chain. The so-called "demand-driven supply network" in modern supply chain management uses automated business processes to sense demand and react to it in real time by linking customers, suppliers, and employees via the Internet. The realization of demand-driven supply network signals the arrival of processes-driven networked economy. As a result, the software industry must develop the methodologies and tools needed to contain the up and coming explosion in the number and complexity of business processes, particularly in the area of supply chain automation. A unique way to enable the reuse of process components in the context of supply-chain management is also discussed in Vitharana, Zahedi, and Jain (2003).

In Figure 4, the scope and complexity of supply-chain processes are illustrated in the context of materials flows in the automotive industry. We will discuss, based on the example, what is involved with dynamic changes in a supply chain.

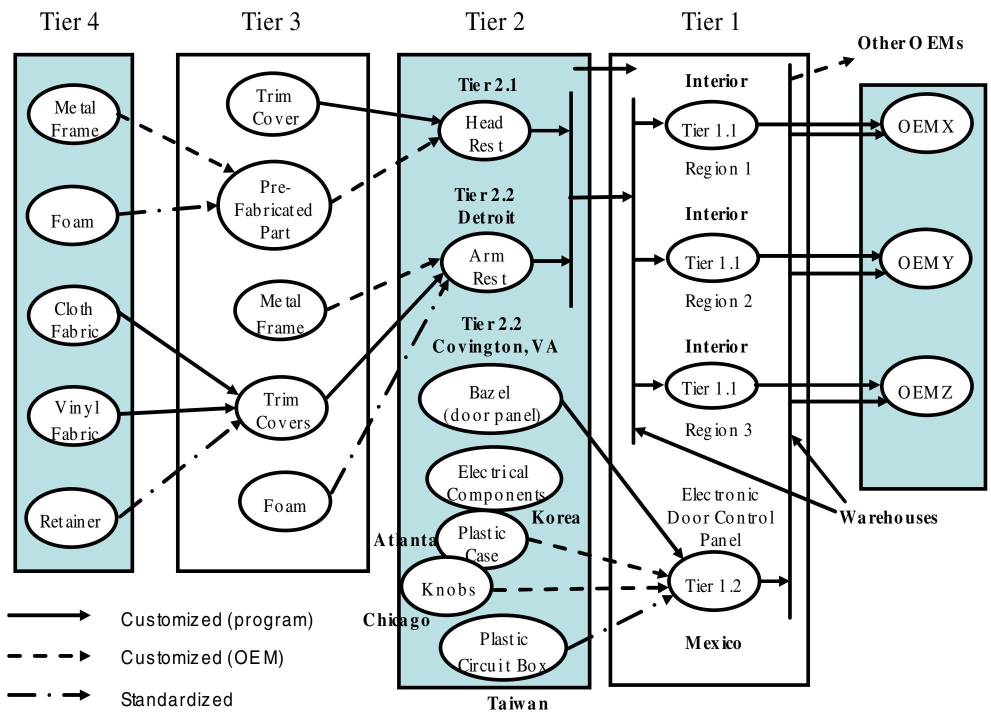

Figure 4: An automotive supply chain (Quoted from Aigbedo and Tanniru 2004)

As given by the Supply-Chain Council, any supply chain process model within a firm can be broken into five stages, i.e., plan, source, make, deliver, and return (Supply-Chain Council 2004). Each of the five stages can interact with another firm's business process, thus creating a supply network consisting of many of these five stages from manufacturing, transportation, and financial service firms. Figure 4 illustrates a segment of supply chain for an OEM in the automotive industry. As shown in the figure, an automotive supply chain typically contains five tiers of suppliers that are dispersed geographically and linked via materials flow from lower tier suppliers to higher tier suppliers. From the workflow perspective, each of the links represents materials flow, facilitated by transportation firms such as UPS and freight liners (Stohr and Zhao 2001). A materials flow is accompanied by documents flow either electronically or by the transportation firms. If the materials flow goes across company boarders, a financial flow would be needed assisted by one or more financial service firms. These supply-chain processes contain both private processes and public processes. By private process, it meant the process encompassing tasks executed within a firm and considered proprietary. On the other hand, a public process is the portion of the supply network that is exposed to the public via a market maker or supply-chain consortium.

These supply-chain processes require frequent redesign as the supply chains can change dynamically due to supplier changes, supply network interruption, firm reorganization, supply network restructuring, and process outsourcing, as discussed below:

- *Supplier changes*. When a new supplier joins a supply network, the process may or may not be redesigned depending on if the supplier already has the necessary process in place. If not, the supplier may need to redesign its process to suit the need of the buyer. The buyer may also need to redesign its process if it needs to modify the process to integrate with the supplier.

- *Supply network interruption*. A supply network can be interrupted if a supplier suddenly drops out of the supply agreement due to bankruptcy or contract breakage. Or, the supplier may change its manufacturing or delivery process, which can cause a major change to its business process and impact its supply process.
- *Firm reorganization*. A company may reorganize itself by selling part of its company, and then a previously internal supplier would become an external supplier, thus causing the accounting process to change. A company may also restructure its warehouse or transportation arrangement, thus leading to a modification of delivery processes.
- *Supply network restructuring*. A sector of the industry may decide to organize into new alliances or the country of the industry joins a new trade organization. All firms in the industry may need to change their business processes to meet the new requirements.
- *Process outsourcing*. A company may decide to outsource part of all its supply-chain operations. Obviously, the new supply-chain processes will have to be redesigned to satisfy the new operational environment.

Companies today face significantly more supply chain challenges than ever before, including increasing supply-and-demand uncertainties, the accelerating pace of product and technology changes, and new trends of manufacturing outsourcing. In addition, the terrorist attacks of September 11 in 2001 and the SARS outbreak in Asia in 2003 are social and natural disasters that caused tremendous disruptions to supply chains. According to Lee (2004), "*To respond to the high degree of uncertainty associated with product variety proliferation and disruptions due to unexpected crises, supply chains need to be agile and flexible to match demand with supply. And companies need to develop supply chains that are adaptable, that respond to the systematic changes of the market and the customer. In addition, companies must be ready to adjust their supply chain structures and strategies when change occurs.*"

Service-oriented architectures can be used to make supply chains more agile and more adoptive because the five reasons of changes in a supply chain can be facilitated with the service-oriented architectures (Figure 2) and with the sense & response services framework, thus leading to what we refer to as service-oriented supply chains. The SOA application in supply chain management represents a grand challenge because the inter-organizational activities will require multiple service-oriented architectures to interact with one another.

Opportunities for Research

The emerging service paradigm offers many opportunities for research. It represents a unique approach to application development and integration. It is heralded to make organizations, their architectures and applications more agile. In this section, we present an overview of possible avenues for research in the realm of service-oriented enterprises and architectures.

- ### Service Design

Services symbolize a way to offer highly interoperable chunks of information system capabilities at various levels of granularity. As Broy et al. (2007, p. 1) highlight, "they emphasize functionality (services), rather than structural entities (components) as the basic building block for system composition." A set of services can be choreographed to form an application to support a specific business process. While services are often built based on specific application requirements, the most gains in the new paradigm can be realized by carefully crafting services that could be (re)used in multiple scenarios.

In this context, service design refers to concepts employed to design such services. In many cases, services are built piecemeal based on specific technical and business needs. Nonetheless, generating a set of services for a particular domain such as human resource function or auto insurance could prove most useful. From a research perspective, the challenge is to embody the domain knowledge and corresponding functionalities in loosely coupled services that then could be used to compose applications for the domain. For instance, once corresponding services in human resource domain are available, a customized payroll application could be composed to support business processes of a specific organization. While our understanding on segmenting domain knowledge in terms of traditional artifacts such as objects is mature (e.g., Gomma 1992), there is little research on how to abstract and package domain knowledge as services that can be marketed and sold as independent products/services, and combined with products/services from multiple sources to built end-to-end solutions.

There has also been a call to design services around typical business processes such as travel reservation or procurement (Crawford et al. 2005). It is argued that service paradigm offers the technical foundation for making business processes accessible within and across enterprises (Leymann et al. 2002). Along these lines, future research could examine methodologies for aligning business processes with corresponding services. The emergence of standards such as Business Process Execution Language (BPEL) for specifying how to define a business process in terms of services could further serve as a catalyst for the construction of services for their alignment with business processes.

A related topic in service design is granularity. Because services vary in their support of various enterprise functions, granularity play a key role in service design. Artus (2007) considers the granularity to mean the number of operations a service provides. Future research could examine the optimal level of granularity as too coarsely granular services are less likely to be reused because of possible "excess baggage" they carry while too finely granular services carry unwanted overhead in their discovery and utilization.

- **Requirements Analysis**

Requirements analysis (RA) plays a key role in traditional application development based on the classical life-cycle model. In the service paradigm, applications are built by composing services possibly sourced from various providers archived and described in some repository. In the instances where such a repository contains domain encompassing services, the requirements analyst could learn about the domain by examining related services. Because analyst's knowledge of the business domain is critical to RA success (Pitts and Browne 2004), future research could examine if and how such a repository could help the analyst acquire the domain knowledge.

Moreover, in traditional application development, requirements are used as the blue print in the subsequent design stage. In service-based development, design takes a much different view. It is likely that the design would turn into an exercise in matching user requirements with existing services. Further research is needed to examine how the service paradigm alters both the requirements analysis and design stages of application development. In cases where a particular requirement does not exactly match with the functionality of existing services, a new service might have to be built which can then be placed in the repository for future use. In the instances where some requirements do not perfectly match services, users could be given the opportunity to alter their requirements based on the cost-benefit analysis of using existing services and building of services anew.

- **Agility**

The service paradigm is expected to make organizations, their architectures and applications more agile (Artus 2007; Crawford et al. 2005; Zhao et al. 2007). While there are numerous anecdotal evidences of gains in agility, there is little empirical research on this topic. As the business landscape constantly changes and global competition intensifies, the organizations need to become more agile. An agile organization could more easily alter its course than a one that is not. For instance, when a more powerful retailer demands that suppliers themselves manage its inventory, a more agile supplier could readily adhere to this requirement. Future research should examine whether organizations that have adopted the services paradigm are more agile than the ones who have not.

From an architectural point of view, it would be interesting to examine whether SOA provides greater agility when compared to others such as component-based infrastructures (e.g., CORBA or DCOM). Empirical studies examining this relationship could investigate how the architecture affects agility outcomes such as the firm's ability to meet changing customer requirements.

Finally, at a more mirco-level, application agility refers to the ability to quickly change the application due to change in a requirement or a bug fix. The question then is whether service-based applications are more agile than applications built from employing traditional methods (e.g., module-based, component-based, etc.). Research needs to examine whether and how service-based applications enhance agility outcomes such as time and effort required to implement change requests, fix bugs, and respond to technology changes, more than applications built from traditional means.

- **Adoption of Service Orientation**

While organizations and their top management have realized the potential of the new service paradigm, its adoption has been sporadic. As some managers are likely to play the waiting game to assess its impact on them in particular and their industry in general, future research should investigate organizational and industry characteristics that influence adoption of the service paradigm. For instance, organizational attributes such as the number of legacy systems and employees' skill level in the service technology are likely to affect service adoption. On the other hand, industry traits such as current industry adoption and level of standardization will impact an industry's adoption which in turn will impact individual firms' decision to adopt the service paradigm.

Several theoretical perspectives have been employed in studying technology adoption. For example, Technology Acceptance Model (TAM) has been widely used to examine innovation adoption in organizations (Davis 1989). This model considers perceived ease of use and perceived usefulness are key antecedents of technology adoption. On the other hand, institutional theory posits that non-choice behaviors emanating from mimetic, normative, and coercive pressures could impact a firm's decision to adopt a new technology (DiMaggio and Powell 1983). These theoretical perspectives along with others such as resource-based view could be employed to investigate adoption of service orientation. With a few exceptions (e.g., Ciganek et al. 2005), there is little research into investigating service adoption.

- **Service Standards**

Realization of service orientation in various business verticals such as banking, insurance, manufacturing, retail, and healthcare heavily depends on standardization. While the development of technical standards such as web services (Ciganek et al. 2005) and business process choreography standards (Curbera et al. 2003) are at an advanced stage, domain specific standards are at the early stage of development. Many interesting research issues in this area exist. Information systems community with its focus on business and technical issues is uniquely positioned to address these issues.

Wide scale adoption of the service oriented model in a specific business domain require development and adoption of domain specific ontologies (Belll et al. 2007) to facilitate service design, description and search. Such ontologies exists in domains like health care (UMLS); however they are non existent in many other domains. The process of developing such ontologies needs to be studied. Another important ingredient of success is standard business architecture for the domain which can serve as the blue print for service design at various levels of granularity and standardization of service standards. More research relating to business architecture description and representation, architecture development process etc. is needed. Finally, standardization of domain specific service interfaces is an important and wide open area of research.

Conclusion

Most experts argue that the service paradigm marks a significant advance in how information systems could enhance intra- and inter-firm business processes. In this paper, we focused on investigating various recent advances in service-oriented enterprises and architectures. In particular, we highlighted current state of the art and opportunities for future research in the emerging paradigm. We hope this discussion fosters further research in this important area.

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